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Fig.4.Graph of control pulses

Comparitive Analysis of Pulse Methods for DC Motor Control

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GOAL OF THE STUDY

DC collector motors are used in control systems of technological devices and in robotics. The most commonly used method for controlling this type of motors is the pulse width modulation (PWM) method of the anchor supply voltage. In the continuous current mode, the current through the anchor increases from an initial value i_0, which is minimal for the self-induction current i_2 during the off state toff of the transistor Q1 (Fig.2).Transistor Q1 is controlled by PWM. The change in current during the on state of the transistor Q1 is described by the equation:

$$i(t) = \frac{(V_S - E_a)}{R_a}\left(1 - e^{-\frac{R_a}{L_a}t}\right) + i_0 e^{-\frac{R_a}{L_a}t} \qquad (1)$$

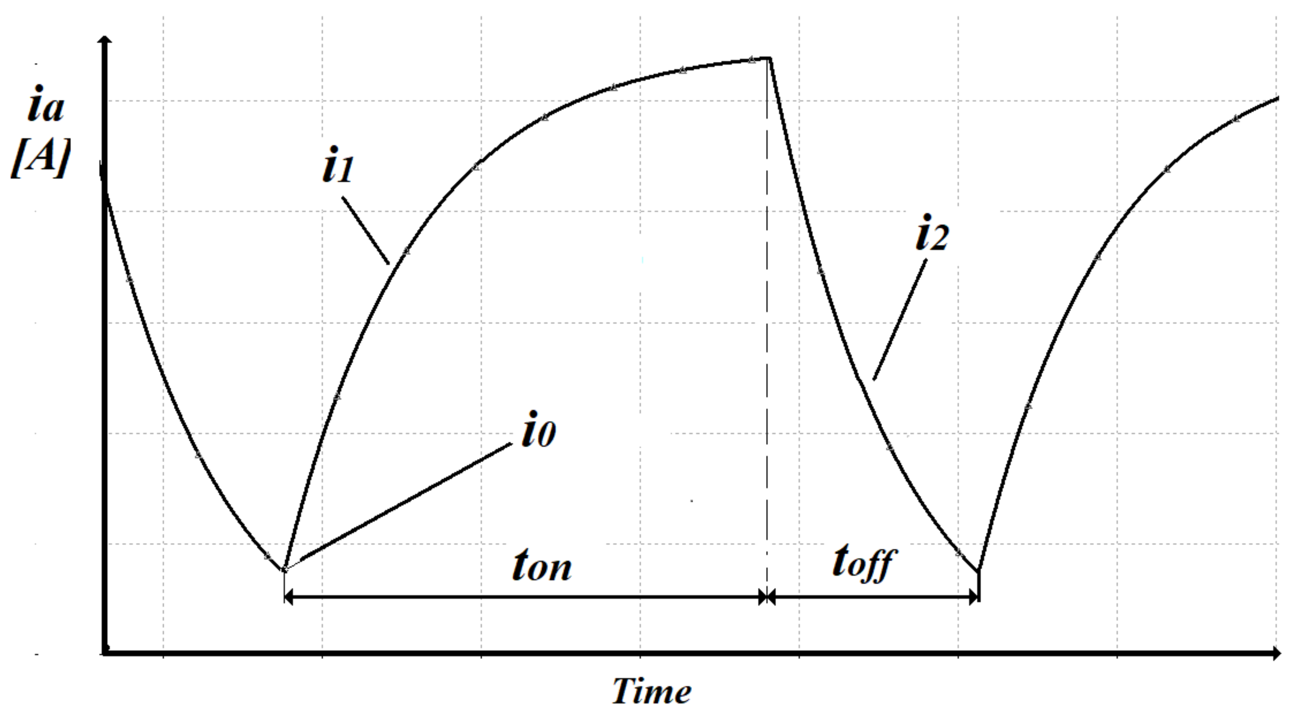

Fig.2. Transients of current in the anchor winding

The purpose of the research and analysis of the obtained results is to compare the consumed electric power, the output mechanical power and the efficiency of the motor in three different control methods.

SHEME FOR INVESTIGATION OF THE METHOD WITH ADDITION OF ENERGY

A scheme with addition of energy in each control pulse for the motor in control by the method of pulse width modulation has been designed and studied (Fig.3).The controlled motor is DC with brushes and with a permanent magnet in the stator.It is designed to control actuators in industry and robotics.The maximum supply voltage *Vs* for the motor is 30V.

The motor shaft is loaded with a constant resistance torque T_R equal to the rated torque of the motor T_{nom}.

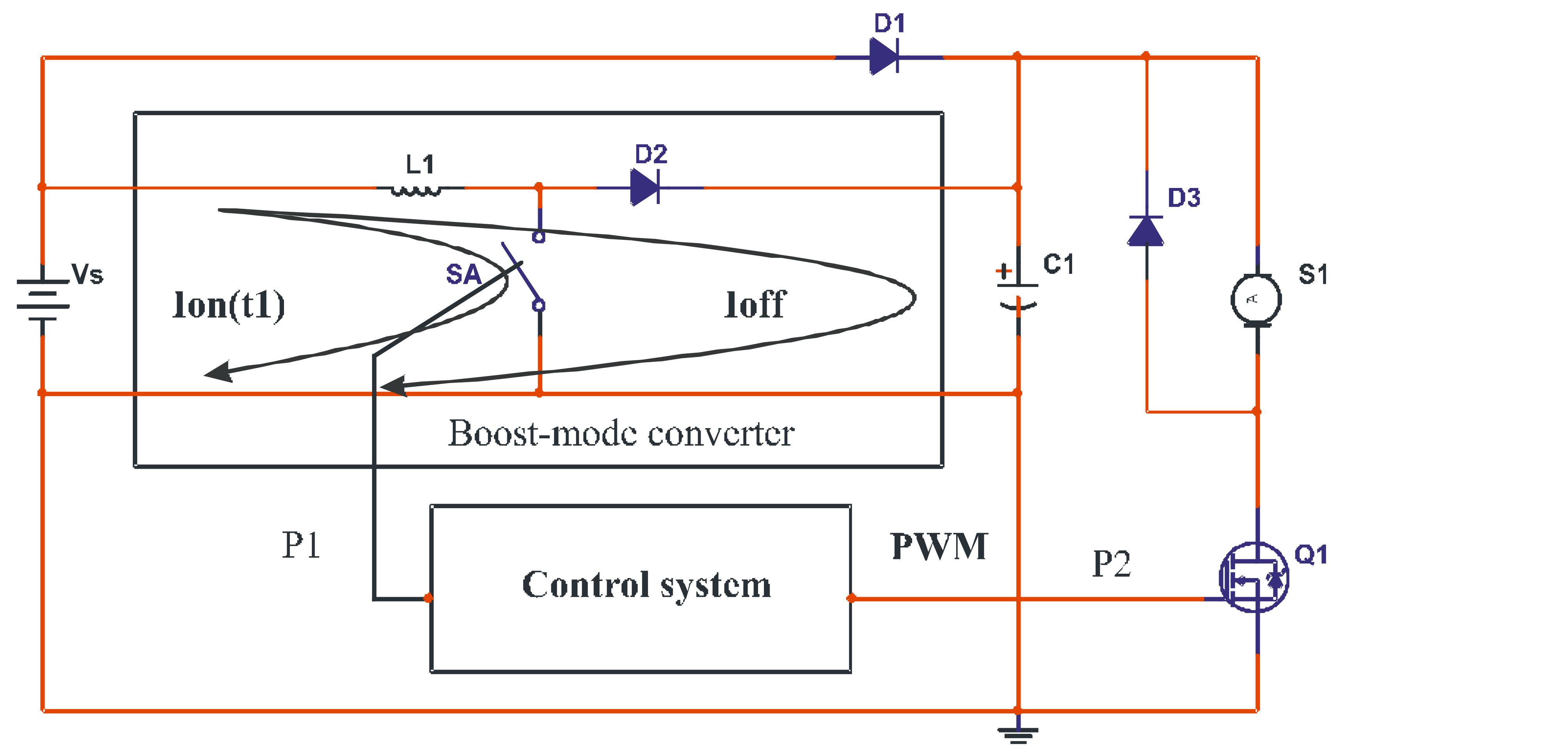

Fig. 3. Scheme for experimental study of transients in the method with the addition of energy

The charging of the capacitor C1 with high voltage generated by the converter takes place after switching off the switch SA at the end of the pulse t(P1).The high voltage supplies anchor winding of the motor at the moment of receipt of the control pulse t(P2) for the transistor (Fig.4).

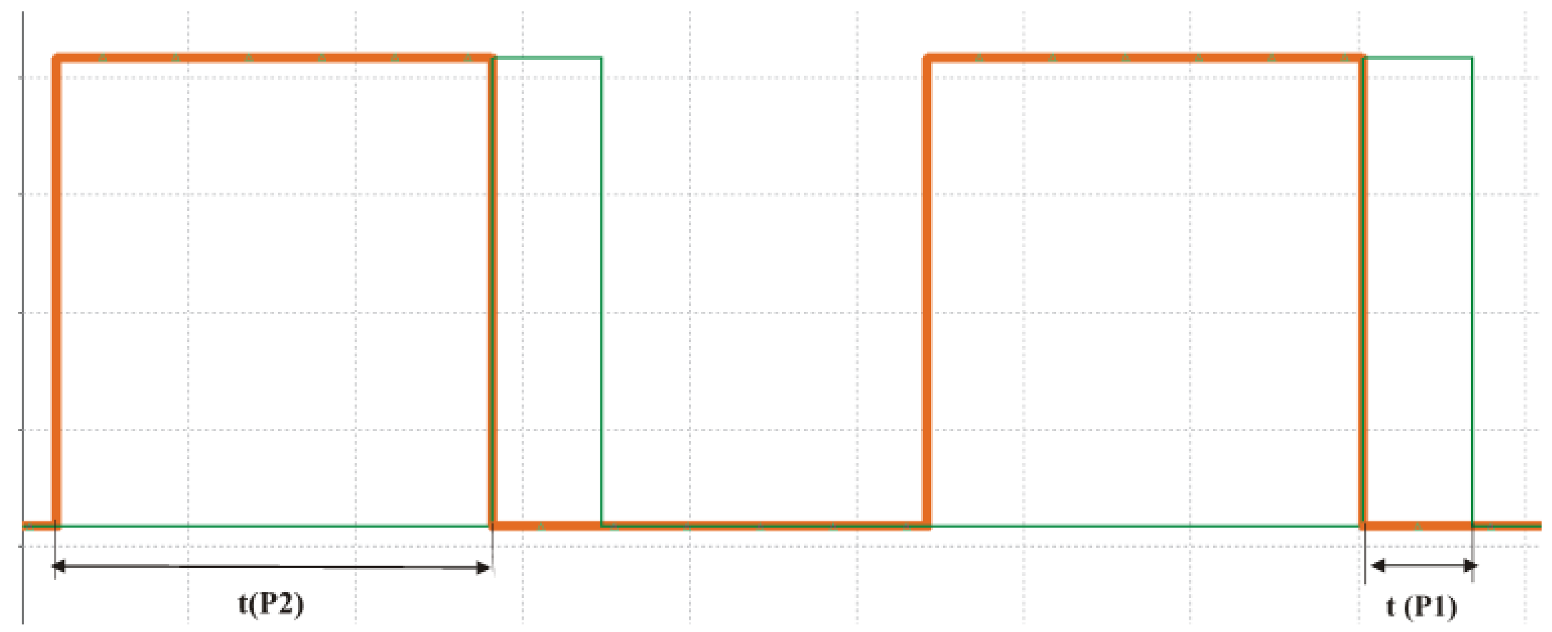

Fig.4. Graph of control pulses

COMPARATIVE ANALYSIS OF THE EXPERIMENTALLY OBTAINED RESULTS

Figure 5 shows the graphical solution of the current equation $i_1(ton)$ (1) when the transistor Q1 is turned on when controlling by both methods and duty cycle *D*=40%. The research was done in the Maple software environment.The theoretically calculated results are close to the results obtained from the experiment. For comparison of the results of the graphical solution in the following figures 6 and 7 are shown oscillograms of the measurements of the change in current in both control methods.

TABLE1

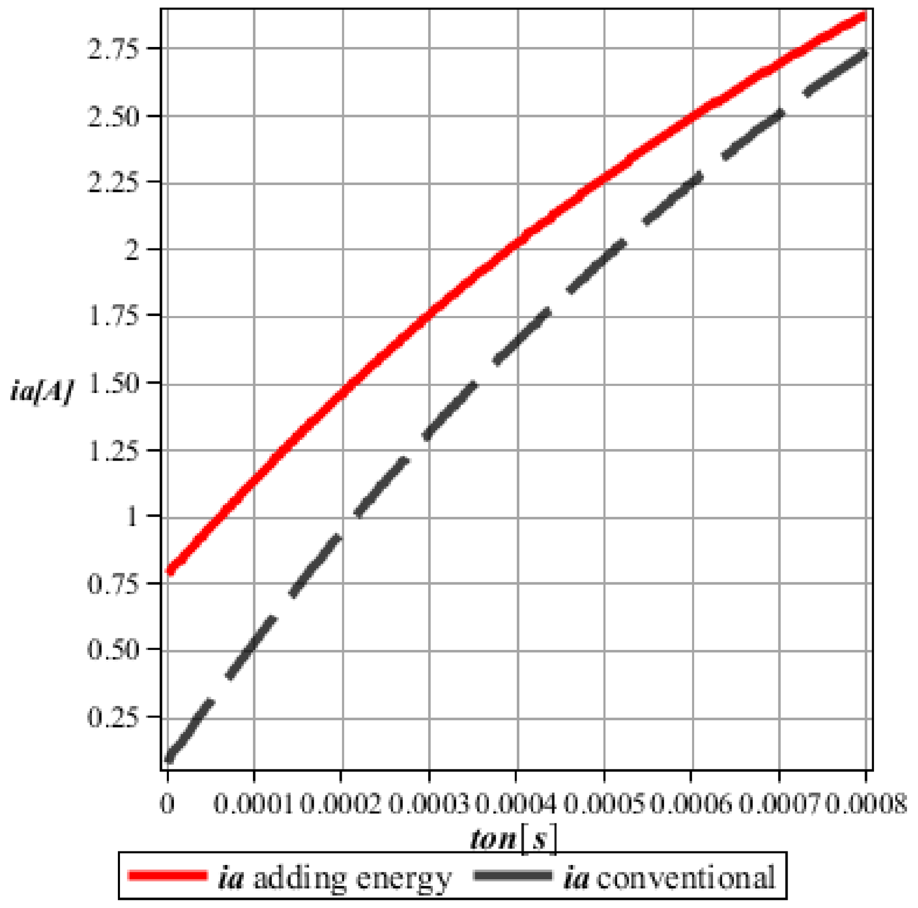

Fig.5. Graphical solution for current i_1 *(ton)* at switch-on of transistor Q1 when controlling by both methods at D = 40%

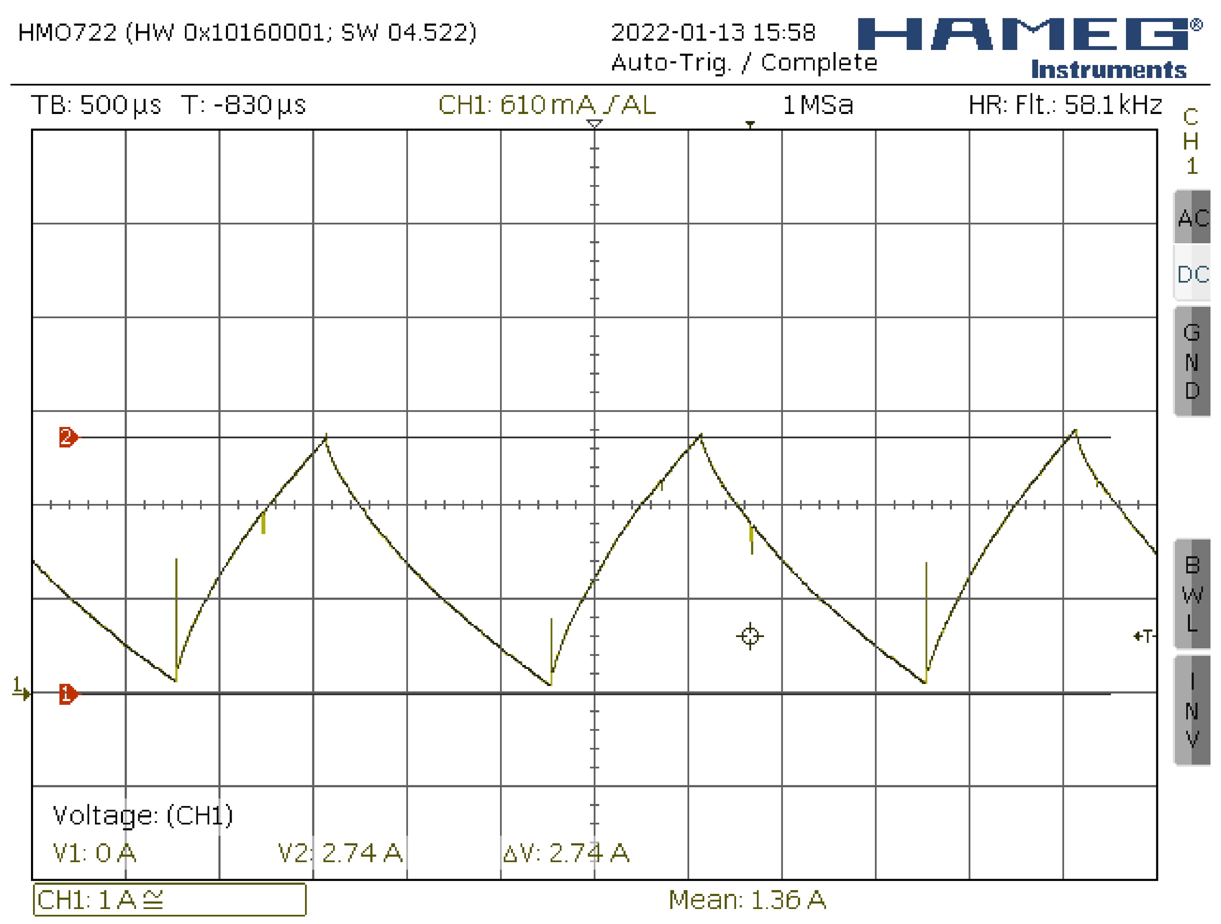

Fig.6. Change of current through the motor anchor at duty cycle D = 40% in the conventional method

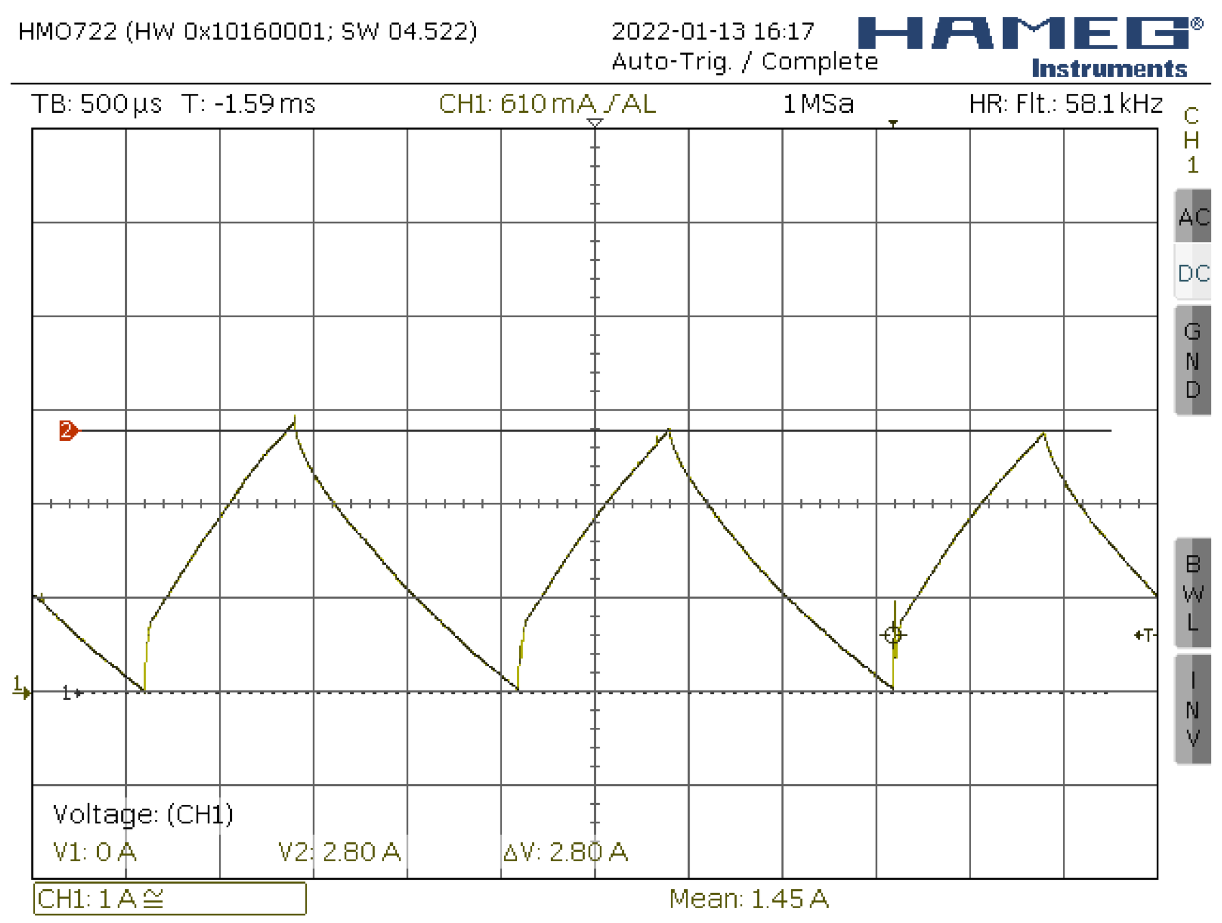

Fig.7. Change of current through the motor anchor at duty cycle D = 40% in the method with addition of energy

Table 1 shows the values of the electric power consumed by the motor when controlled by three different methods: DC voltage supply Pel (DC), the conventional method of pulse control Pel (conventional method), and the method of adding energy Pel (with addition of energy). Table 2 shows the change in the developed mechanical power from the motor shaft as a function of the supply voltage of the anchor.

TABLE1

D[%]	*Vave[V]*	*Pel [W]* DC	*Pel[W]* with addition of energy	*Pel[W]* conventional method
20	6	6.6	8.4	8.16
30	9	12.06	13.68	13.32
40	12	18.84	20.52	19.80
50	15	25.95	27.90	26.70
60	18	35.10	35.10	34.56
70	21	43.89	44.73	43.47
80	24	53.52	52.56	51.60

TABLE2

D[%]	*Vave[V]*	*Pmech [W]* DC	*Pmech[W]* with addition of energy	*Pmech[W]* conventional method
20	6	2.21	1,71	1,05
30	9	5.48	6,42	5,15
40	12	10.14	11,02	9,89
50	15	15.41	16,33	15,34
60	18	23.45	22,28	21,11
70	21	29.63	28,38	27,33
80	24	38.14	35,51	34,39

The change in the developed mechanical power as a function of duty cycle in three studied control methods is shown graphically in the following diagram (Fig. 8). Table 3 compares the efficiency of the DC motor when driving with the three methods.

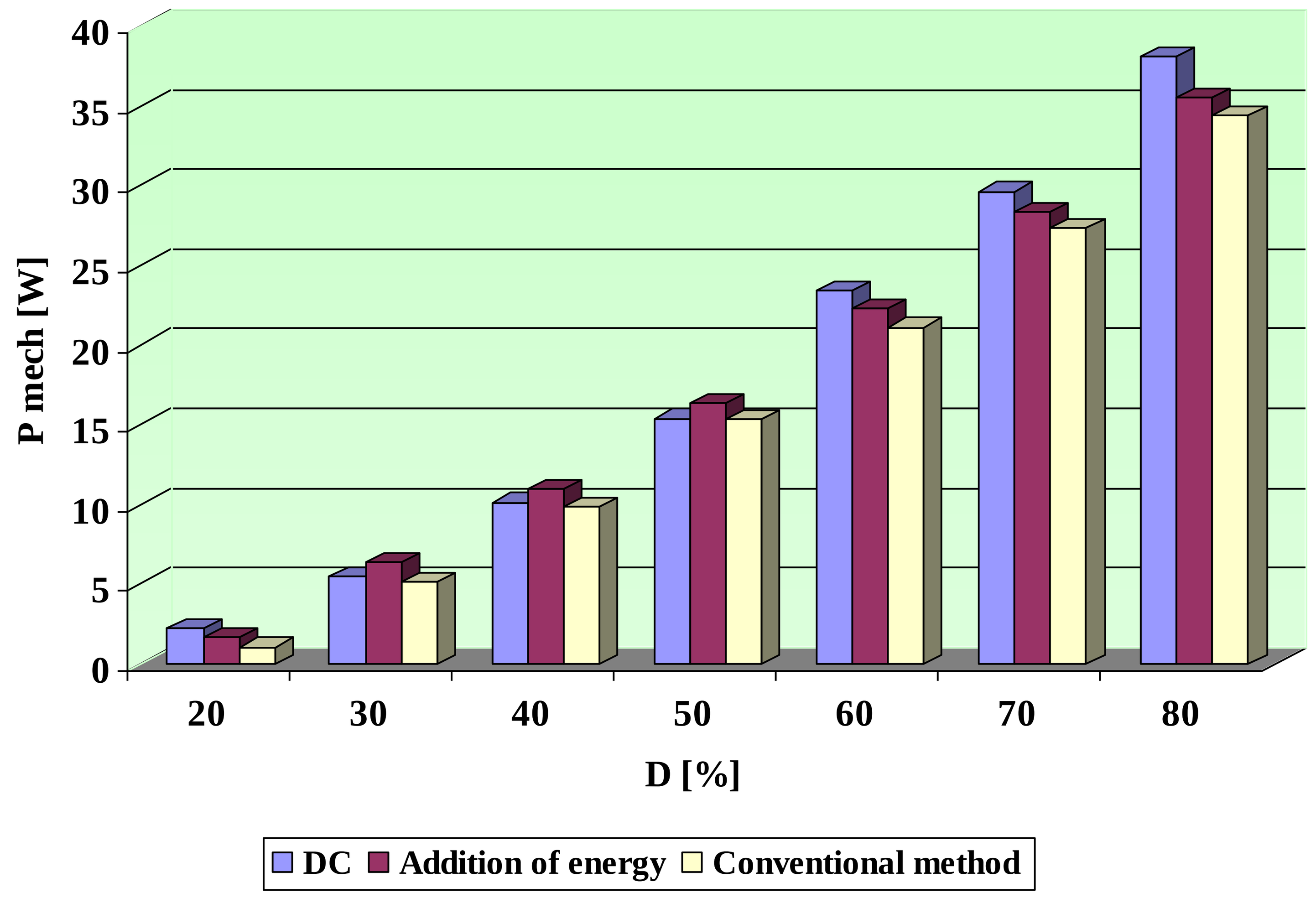

Fig.8. Developed mechanical power from the motor shaft in three control methods

TABLE 3

D[%]	*Vave[V]*	***η** [%]* DC suplay	***η*** [%] with addition of energy	***η*** [%] conventional method
20	6	33.5	20.36	12.87
30	9	45.44	46.93	38.66
40	12	53.82	53.70	49.95
50	15	59.38	58.53	57.45
60	18	66.81	63.48	61.08
70	21	67.51	63.45	62.87
80	24	71.26	67.56	66.60

CONCLUSIONS

The obtained experimental studies show the advantages of the proposed method by adding energy to control pulses for the anchor winding of motor. At low motor speeds, the developed torque of the shaft is greater compared to control from a DC voltage source. With pulse control by the PWM method with the addition of energy, the motor develops higher rotation speeds compared to the conventional method in the entire range of speed control.The proposed and researched method is suitable for control of executive motors in digitally controlled machines and for control of robots.

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